FUEL SAVINGS & AERODYNAMIC DRAG REDUCTION FROM RAIL CAR COVERS

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ABSTRACT

The potential for energy savings by reducing the aerodynamic drag of rail cars is significant. A previous study of aerodynamic drag of coal cars suggests that a 25% reduction in drag of empty cars would correspond to a 5% fuel savings for a round trip [1]. Rail statistics for the United States [2] report that approximately 5.7 billion liters of diesel fuel were consumed for coal transportation in 2002, so a 5% fuel savings would total 284 million liters. This corresponds to 2% of Class I railroad fuel consumption nationwide. As part of a DOE-sponsored study, the aerodynamic drag of scale rail cars was measured in a wind tunnel. The goal of the study was to measure the drag reduction of various rail-car cover designs. The cover designs tested yielded an average drag reduction of 43% relative to empty cars corresponding to an estimated round-trip fuel savings of 9%.

APPROACH

The measurements were made in the NASA-Ames 15- by 15-Inch Low-Speed Wind Tunnel. Five 1:87-scale hopper-type rail cars were mounted on a scale train track (Fig. 1) with the middle car connected to the upwind car by a 9-N load cell and disconnected from the downwind car. All cars except the middle car were affixed to the track to prevent motion. In terms of full-scale values, the cars measure approximately 3 m wide, 3.4 m high, and 14.6 m long with a gap between cars of 1.7 m.

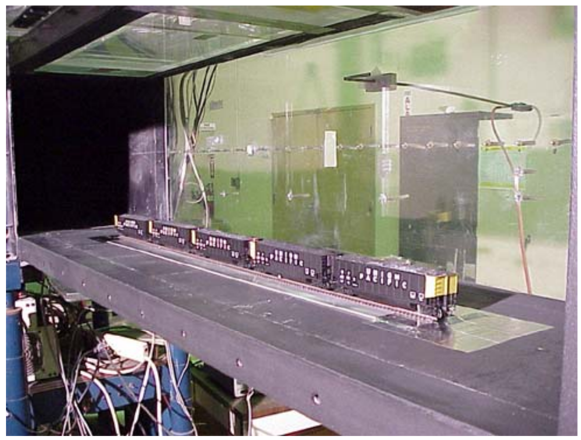

Figure 1. Five coal cars mounted in wind-tunnel

This configuration was tested at a free-stream velocity of 65 m/s with and without simulated coal in all cars. This relatively high tunnel speed was chosen to maximize the measured drag and minimize measurement uncertainty. Due to the nature of sharp-edged bluff-body flow fields, the differences in model scale and speed are not expected to significantly affect the experimental results. Previous larger-scale results [3] compare favorably with the current study and validate the small-scale methodology.

Several cover designs were applied to all five cars and the resulting drag on the middle car was measured for each configuration. In addition to the flat cover (flush with the top of the rail car), three domed cover designs were tested with differing heights and/or end geometries. The 50-deg and vertical end configurations (Fig. 2-3) had a dome height of 1 m, while an addition 50-deg end configuration was tested with a height of 0.5 m. The five-car combination was tested at yaw angles from zero to 10 deg to determine the effects of crosswind.

Figure 2: 50-deg end domed cover

Figure 3: Vertical end domed cover

EXPERIMENTAL RESULTS

In rail-car analysis, the aerodynamic resistance is the force opposite the direction of travel and is identical to the axial force measured by the load cell in this experiment. The drag coefficient (C_D) for each configuration was calculated by dividing the axial force by the dynamic pressure ($1/2\rho V^2$, where ρ is air density and V is train velocity) and the cross-sectional area of the empty model rail car.

For each configuration, measurements were made in 2-deg increments for yaw angles from zero to 10 deg. Using the variation of drag with yaw angle, wind-averaged drag coefficients were computed using the SAE Recommended Practice [4]. This practice assumes that the mean wind speed in the United States of 11 kph has an equal probability of approaching the vehicle from any direction. This mean wind speed and the vehicle velocity were used to calculate a weighted average of the drag coefficient at various yaw angles. The values for wind-averaged drag reduction reported in this paper were computed for a speed of 65 kph.

The effects of the rail-car covers and the simulated coal loading are presented in Fig. 4. Relative to the empty rail car, the full coal car indicated significantly less drag ranging from 29% to over 41% for yaw angles of zero to 10 deg, respectively. The rail car covers reduced the aerodynamic drag even relative to the full car configuration. The measurement accuracy and repeatability resulted in error bars that increase with yaw angle as shown on the empty-car drag curve. Since the differences between the cover data is of the same order as that of the error bars, it is difficult to make any meaningful distinction between the cover designs except that the flat covers generate marginally higher drag at yaw angles below 8 deg. The median wind-averaged drag reduction for all four cover designs was 43% which would result in a round-trip fuel savings of approximately 9% based on the prediction of Ref. 1.

SUMMARY

Using the coal transportation statistics [2], the estimate fuel savings [1], and a diesel fuel cost of R10/L (for ease of scaling), estimates of the cost savings per tonne and carload were calculated and are listed in Table 1. Since these estimates include numerous assumptions and uncertainties, it is recommended that the fuel savings be verified by full-scale trials. At the date of publication, fuel savings measurements were underway by railroad operators in the United States. Preliminary results are said to be "better than expected".

Table 1: Estimated cost savings (based on R10/L) for rail transportation of coal

Per tonne	R8.16
Per carload	R819

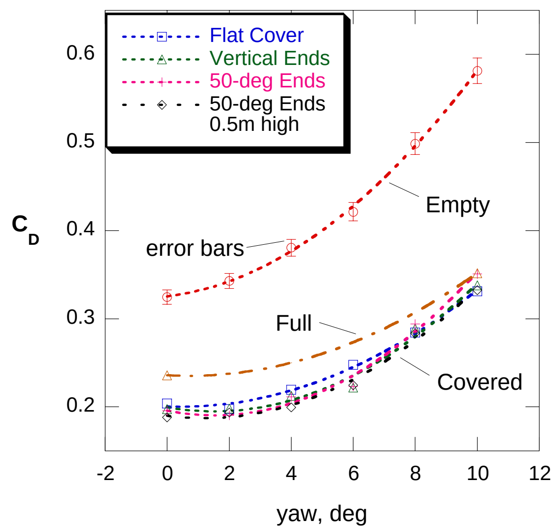

Figure 4: Drag coefficient vs. yaw angle of rail cars with and without covers

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